Admission Chest CT Complements Fiberoptic Bronchoscopy in Prediction of Adverse Outcomes in Thermally Injured Patients

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In burned patients, inhalation injury can result in progressive pulmonary dysfunction, infection, and death. Although bronchoscopy is the standard for diagnosis, it only assesses the proximal airway and does not provide a comprehensive analysis of pulmonary insult. Chest radiographs have not been proven helpful in diagnosis of inhalation injury. Our hypothesis is that a CT scan alone or in conjunction with bronchoscopy can be used as a prognostic tool for critically ill burn patients, especially those with inhalation injury. The authors performed a retrospective study of all patients admitted to the U.S. Army Institute of Surgical Research Burn Center between 2002 and 2008 with chest CT within 24 hours of admission. They divided subjects into two groups, those with evidence of inhalation injury on bronchoscopy and those without. They used a radiologist's score to assess the degree of damage to the pulmonary parenchyma. The primary endpoint was a composite of pneumonia, acute lung injury/acute respiratory distress syndrome, and death. The inhalation injury group consisted of 25 patients and the noninhalation injury group of 19 patients. Groups were not different in age, TBSA burned, and percentage full-thickness burn. By multiple logistic regression, detection of inhalation injury on bronchoscopy was associated with an 8.3-fold increase in the composite endpoint. The combination of inhalation injury on bronchoscopy and a high radiologist's score was associated with a 12.7-fold increase in the incidence of the composite endpoint. Admission CT assists in predicting future lung dysfunction in burn patients. (J Burn Care Res 2012;33:532–538)

In burn patients, inhalation injury is an independent risk factor for mortality, along with TBSA burned and age.[1–3] The sequelae of inhalation injury include progressive pulmonary dysfunction and infection, resulting in prolonged ventilator dependence.[4–7] Inhalation injury results in increased fluid requirements, formation of bronchoalveolar casts, and difficulty in adequate gas exchange. These complications then necessitate

adjunctive therapeutic strategies such as high-frequency percussive ventilation, nebulized heparin, and increased fluid resuscitation.[3,4,8,9]

On the premise that direct visual inspection conveys meaningful information about upper airway injury, bronchoscopy is accepted as a "gold standard" for diagnosis of inhalation injury.[10,11] However, degree and depth of damage to main airway mucosa cannot at present be accurately distinguished by eye. Bronchoscopy has also been shown to have poor predictive value in assessing the degree of pulmonary dysfunction or progression to acute lung injury (ALI) or acute respiratory distress syndrome (ARDS) and does not depict lung parenchymal injury.[12,13]

Various modalities have been evaluated to increase the sensitivity and specificity of diagnosing inhalation injury. These include carbon monoxide (CO) measurement, bronchoscopy with cytology and biopsy,[14,15] serial chest x-rays,[16,17] radionuclide imaging with technetium and xenon,[18,19] and pulmonary

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function testing.[20] To date, these diagnostic modalities have been found to be insufficiently sensitive, too invasive, or too cumbersome. CT scan can be extremely useful in documenting the heterogeneity of parenchymal damage. It can show regional density distribution and temporal progression of damage as well as improvement in regional aeration in the lung.[21] We previously performed an ovine study of CT scans in smoke inhalation injury, finding that a radiologist's score (RADS) can detect severity of inhalation injury at 24 hours.[22] In addition, case reports of chest CT scans in patients with inhalation injury suggest clinical utility.[23,24]

The purpose of this study was to investigate the association between findings on lung CT scans (acquired in the first 24 hours of admission to the burn center) with outcome in burn patients. Our hypothesis is that a CT scan alone or in conjunction with bronchoscopy can be used as a prognostic tool for critically ill burn patients, especially those with inhalation injury.

METHODS

This study was conducted under a protocol reviewed and approved by the institutional review board. Inclusion criteria were all patients aged 18 years or older admitted to our burn center from June 2002 to December 2008 who had a CT scan of the chest with or without intravenous (IV) contrast within 24 hours of admission.

Exclusion criteria were patients younger than 18 years, patients with preexisting parenchymal lung disease, and patients with a diagnosis of ARDS, ALI, or transfusion-related lung injury before the CT scan. Patients who had CT scans of the chest >24 hours after admission and any patient with lung trauma or lung surgery before the CT scan were also excluded.

Data were retrospectively analyzed from inpatient electronic medical records. Patients with inhalation injury diagnosed on bronchoscopy comprised the "inhalation injury group" and those without inhalation injury diagnosis on bronchoscopy the "no inhalation injury group."

The following data were recorded and compared: age, TBSA, percent full-thickness burn (% FT), injury severity score (ISS), presence of tracheostomy, arterial carboxyhemoglobin levels (COHb), and the ratio (PFR) of the partial pressure of oxygen in arterial blood (PaO_2) to the fraction of inspired oxygen (FiO_2). In addition, the following variables were recorded: time in days from burn injury to CT scan, number of 1-cm slices per CT scan, and use of IV contrast. Outcome variables included 28-day

ventilator-free days, mortality, incidence of pneumonia, and ALI or ARDS during admission.

Resuscitation, Wound Care, and Ventilator Management

On arrival to the burn center, burn wound depth was assessed and patients were resuscitated with IV crystalloid solution based on TBSA. Fluids were titrated to achieve a urine output of 30 to 50 ml/hr. Albumin (5% in normal saline) was administered during hours 24 to 48 postburn. (It was started 12 hours postburn if high resuscitation volumes were required at that time.) Wounds were assessed and debrided on admission, and excision and grafting was performed after patients were adequately resuscitated. For patients with a history or physical examination suspicious for inhalation injury, a fiberoptic bronchoscopy was performed. A range of findings on bronchoscopy was considered positive for inhalation injury to include carbonaceous deposits, mucosal erythema, mucosal sloughing, or mucosal ulcerations. (Throughout this article, the term "inhalation injury" is taken to mean the presence of such bronchoscopic evidence of inhalation injury.) In patients with evidence of inhalation injury on bronchoscopy, high-frequency percussive ventilation and nebulized heparin were initiated. Daily spontaneous breathing trials were performed.

CT-Scan Analysis

Chest CT scans were acquired from a digital scan repository and analyzed by an experienced, board-certified radiologist who was blinded to outcomes and to group assignment. The radiologist scored each CT scan according to the grading system previously described in a study of ovine smoke inhalation.[20] Briefly, CTs from each patient were systematically evaluated using 1-cm axial slices from the apex to the level of the diaphragm. The left and right lung fields in each slice were divided into four quadrants, and each quadrant was assigned a score from 0 to 3 corresponding with a range of severity of findings (see Table 1). The highest, single score within a quadrant was assigned to the final score, and a total score for each slice was calculated (see Figure 1). The total score for each slice was then summed for the entire

Table 1. RADS scoring

Finding	Score
Normal	0
Increased interstitial markings	1
Ground glass opacification	2
Consolidation	3
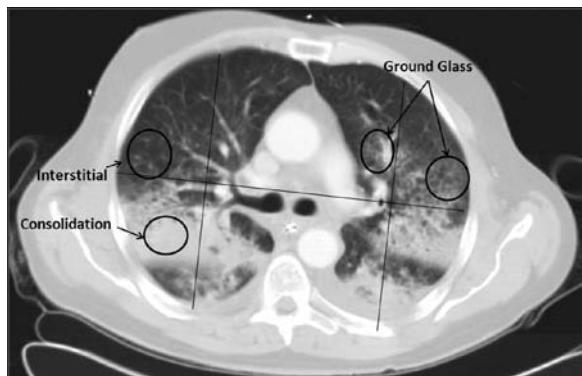
Figure 1. Example of RADS findings.

CT scan to obtain the overall RADS. To normalize the score according to the number of axial CT scan slices, the total RADS was divided by the number of slices read per CT to obtain a RADS per slice. The RADS per slice was used for statistical comparisons between the groups.

A ventilator-free day was defined as the number of days after admission from day 0 to day 28 alive without ventilator assistance for at least 24 consecutive hours. Pneumonia was defined according to clinical criteria and a quantitative culture from bronchoalveolar lavage as described by the American Thoracic Society and the Infectious Disease Society of America.[25] If the culture grew coagulase-negative *Staphylococcus* or common skin flora, the illness was not considered pneumonia. ALI and ARDS were defined according to the American-European Consensus conference.[26]

Our primary endpoint was composite of death and/or ALI/ARDS, or pneumonia. These endpoints were chosen as clinically significant sequelae of inhalation injury.

Statistical Analysis

As appropriate, the χ^2 or Fisher's exact test was used for categorical variables and Student's *t*-test or the Kruskal–Wallis for continuous variables. Univariate analysis was performed to identify potentially significant differences between patients with and without the composite endpoint. Multivariate logistic regression analysis was then used to identify independent risk factors for the composite endpoint. Spearman correlation coefficients were calculated to determine interaction between the explanatory variables used in the multiple logistic regression models. Statistical analyses were performed by using a commercially available statistical software package (SAS 9.1; SAS Institute, Inc, Cary, NC). Statistical significance was accepted at $P \leq .05$.

Table 2. Patient characteristics*

Variable	Inhalation Injury, N = 25	No Inhalation Injury, N = 19	P
Age (yr)	35 (26, 42)	32 (23, 54)	.67
TBSA	19 (5, 53)	19 (10, 34)	.85
% Full-thickness burn	0 (0, 27)	3 (0, 18)	.97
ISS	20 (12, 34)	9 (4, 25)	.0083
IV contrast	79 (15)	60 (15)	.21
Tracheostomy	5.3 (1)	28 (7)	.11
COHb level	0.9 (0.4, 1.5)	1.2 (0.7, 1.9)	.36

* Expressed as median (Q1, Q3) or % (total).

ISS, injury severity score; *IV*, intravenous; *RADS*, radiologist score; *COHb*, carboxyhemoglobin.

RESULTS

Between June 2002 and December 2008, 2376 patients were admitted to the burn center. Of these, 109 were potential subjects. On screening the medical records, we excluded 47 patients because of the presence of primary lung trauma or active lung injury or infection at the time of the CT scan or the absence of a diagnostic bronchoscopy. Another 18 patients were excluded because their CT scans were acquired outside the 24-hour window from admission. Twenty-five patients were included in the inhalation injury group and 19 in the no inhalation injury group. There was no difference in age, TBSA, % FT burn, use of CT scan with IV contrast, tracheostomy, or COHb level. ISS was higher in the inhalation injury group (median: 20, interquartile range [IQR]: 12–34) than in the no inhalation injury group (median: 9, IQR: 4-25; $P = .0083$; see Table 2).

The RADS (median: 109, IQR: 74–146 vs median: 57, IQR: 12–126; $P = .03$) and the RADS per slice (median: 7.1, IQR: 4.4–9.7 vs median: 3.0, IQR: 0.2–7.2; $P = .03$) were significantly higher in the inhalation injury group (see Table 3). When modeling RADS per slice as a binary variable (> or $\leq$8),

Table 3. Results*

Variable	Inhalation Injury, N = 25	No Inhalation Injury, N = 19	P
RADS	109 (74, 146)	57 (12, 126)	.03
No. CT slices	17 (16, 20)	17 (16, 19)	.87
RADS per slice	7.1 (4.4, 9.7)	3.0 (0.2, 7.2)	.03
RADS $\geq$ 8	36 (9)	16 (3)	.181
PFR	252 (113, 407)	284 (130, 504)	.32

* Expressed as median (Q1, Q3) or % (total).

RADS, radiologist score; *PFR*, arterial oxygen tension to fraction of inspired oxygen ratio.

Table 4. Outcomes*

Variable	Inhalation Injury, N = 25	No Inhalation Injury, N = 19	P
Ventilation-free days	20 (0, 25)	26 (19, 28)	.15
Pneumonia	47 (9)	16 (4)	.33
ALI/ARDS	79 (15)	8 (2)	.0014
Mortality	26 (5)	8 (2)	.68
Composite endpoint	89 (17)	20 (5)	<.0001

* Expressed as median (Q1, Q3) or % (total).
ALI, acute lung injury; *ARDS*, acute respiratory distress syndrome.

there were three patients in the no inhalation injury group who had RADS per slice ≥8.

There was no significant difference in ventilation-free days, incidence of pneumonia, or mortality (Table 4). However, ALI/ARDS was significantly higher in the inhalation injury group (79 vs 8%; $P = .0014$), and the inhalation injury group had a significantly higher composite endpoint incidence (89 vs 20%; $P < .0001$) (see Table 4).

We then performed an univariate analysis to identify significant differences between those patients with vs those without the composite endpoint (see Table 5). There were no significant differences in age, ISS, PFR, days to CT, total RADS, RADS per slice, or COHb level between those with and those without the composite endpoint. The TBSA and % FT burn were higher in patients with the composite endpoint. In addition, more patients had inhalation injury (by bronchoscopy) in the

Table 5. Univariate analysis for composite outcome*

Variable	Composite Endpoint Present (n = 22)	Composite Endpoint Absent (n = 22)	P
Age (yr)	41.4 (22.9)	40.4 (16.8)	.8697
TBSA	41.5 (30.1)	16.9 (16.0)	.006
% Full thickness	22.7 (27)	4.4 (9.1)	.0057
Inhalation injury	17 (77%)	8 (36%)	.0062
ISS	26.2 (10.2)	11.5 (9.2)	.2602
PFR	237.2 (154.3)	341.9 (210.5)	.0824
Days to CT	2.09 (2.19)	1.58 (1.59)	.3893
Total RADS	117.4 (96.2)	85.8 (55.2)	.1906
RADS per slice	6.8 (5.3)	5.1 (3.5)	.2115
RADS > 8	8 (36%)	4 (18%)	.1757
COHb level	4.04	1.25	.1305

* Composite outcome: death, ALI/ARDS, and/or pneumonia; values are expressed as mean (±SD).
ISS, injury severity score; *PFR*, arterial oxygen tension to fraction of inspired oxygen ratio; *RADS*, radiologist score; *COHb*, carboxyhemoglobin.
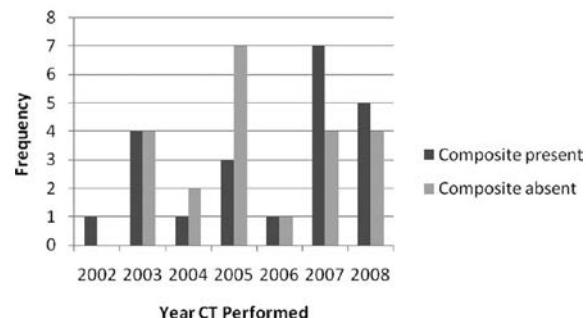

Figure 2. CT scan distribution by year.

group with the composite endpoint (see Table 5). When modeling RADS per slice as a binary variable (> or ≤8), the difference between groups was not significant (see Table 5). The distribution of CT scans by year for each group is displayed in Figure 2.

While controlling for TBSA and % FT burn, we then performed a multiple logistic regression to identify independent risk factors for the composite endpoint using the above variables. Inhalation injury was retained as a predictor of the composite endpoint (odds ratio [OR]: 8.3, 95% confidence interval [CI]: 1.3–49.1; $P = .02$). When the regression analysis was repeated with a set cutoff value (>8) for RADS per slice and the other variables as above, again only inhalation injury was a significant predictor of composite outcome (OR: 8.6, CI: 1.5–48.2; $P = .01$).

To identify the effect of RADS >8 in combination with inhalation injury, we combined these into a single binary variable. The combination of RADS per slice >8 and inhalation injury was predictive of the composite outcome with a greater OR than inhalation injury alone (OR: 12.7, CI: 1.1–153.7; $P = .05$) (see Table 6).

DISCUSSION

The main finding of this retrospective study is that the radiologist's interpretation of the admission chest CT

Table 6. Logistic regression predictor of composite outcome*

Variable	P	Odds Ratio	95% Confidence Interval Limit
Inhalation injury + RADS per slice >8.0	.03	12.7	1.1–153.7
TBSA	.07	1.045	0.0996–1.096
% Full-thickness burn	.7	1.013	0.938–1.093

* Composite outcome: death ALI, ARDS, and/or pneumonia.
RADS, radiologist score.

scan added to the prognostic value of the presence of inhalation injury (as diagnosed by fiberoptic bronchoscopy) in predicting a composite outcome of death, ALI/ARDS, and pneumonia. This clinical study was built on earlier animal work done at this Institute. In an ovine study of smoke inhalation injury, Park et al[22] found that an expert radiologist's interpretation of the chest CT scan enabled accurate stratification of uninjured controls and mild, moderate, and severe smoke inhalation injury at 24 hours. In that study, the RADS also outperformed semiautomated computerized analysis of the same CT scans. We used a similar method of analysis for interpreting the CT scans in this study.

To date, this is the largest study evaluating the utility of chest CT scan in acutely burned patients in predicting outcome. During our retrospective review, we used a range of findings to diagnose inhalation injury. Furthermore, a systematic grading system for bronchoscopic findings is not used in our institution. However, previous studies have shown that bronchoscopic grading systems do not correlate with the development of ARDS.[13,27] This may be attributable to various toxins that are inhaled in addition to direct thermal or smoke injury to the airways. The benefit of a CT scan in characterizing pulmonary abnormalities in our patient population is likely because of the ability of CT to image the distal airways and lung parenchyma in fine detail. In contrast, bronchoscopy only visualizes the proximal, large airways. Proximal and distal findings may differ for two reasons. First, the heat content of inhaled gases diminishes as they pass through the airways. Second, the particulate content of the smoke mixture affects deposition site, such that heavier particles and larger aerosols are deposited more proximally. Therefore, a CT scan may provide additional information about the overall burden of injury to the lungs in patients with inhalation injury.

The value of CT scan in assessing the severity of lung injury has been described in other nonburn studies. A retrospective analysis of chest CT scans in 44 patients with ARDS showed that an increase in the severity of findings on CT scan by a radiologist's interpretation was independently associated with mortality.[28] In another study, CT scan findings in ARDS survivors 6 to 10 months later also correlated with the severity of ARDS as measured by the Murray Lung Injury score.[29] In a retrospective study, Owens et al[30] showed a strong correlation between the Murray Lung Injury score and the fraction of abnormal lung tissue in the acute phase of ARDS on a CT scan as interpreted by a radiologist. Gattinoni et al[31] have also developed radiologic scoring systems

for ARDS based on CT scans as a way to improve diagnostic accuracy and to assess the efficacy of various therapeutic strategies.

We also reviewed plain chest radiographs in our patient population. There was a range of findings, but they were subjective and not quantifiable. Therefore, it was not possible to objectively compare plain radiographs of the chest between our study groups. In contrast, CT scan findings in the chest offer a more readily quantifiable assessment of the lung parenchyma. Although other CT scoring systems exist for conditions including cystic fibrosis and ARDS, these are not in widespread clinical use and have not been validated in large, prospective settings. We chose to base our scoring system on a previous ovine study of smoke inhalation injury because of its direct clinical applicability. Currently, no universal grading system for inhalation injury exists. The practice of diagnosing inhalation injury is based on a combination of history (injury within a closed space), physical examination (facial burns, carbonaceous sputum, hoarseness, stridor), laboratory findings (elevated COHb and alveolar-arterial oxygen gradient), and bronchoscopy. None of these criteria alone are infallible predictors of the sequelae of inhalation injury. A recent appraisal of the current status of research progress on inhalation injury made a universal diagnosis and grading system for inhalation injury a priority.[32] An accurate method of stratifying patients with severe inhalation injury would greatly assist clinicians in both improving patient care and managing resources, because patients with inhalation injury have been shown to have increased fluid resuscitation volumes.[32–34] In addition, patients with inhalation injury benefit from specialized therapeutics such as high-frequency percussive ventilation and inhaled heparin.[35,36] Over time, the availability, speed, and imaging capabilities of CT scans have improved, making them useful adjuncts for patients with inhalation injury.

There were several limitations of our study that must be addressed. We accepted positive findings on fiberoptic bronchoscopy as diagnostic of inhalation injury. Therefore, the meaning of a negative bronchoscopy in conjunction with a high RADS is unclear at this time. The combination of inhalation injury on bronchoscopy with a RADS per slice >8 increased the OR from 8.6 to 12.7 in predicting the severe sequelae of inhalation injury. This suggests that the addition of CT scan to the care of patients with inhalation injury may have prognostic utility. However, these two ORs had overlapping CIs. This could be because of the small patient population in this study. Also, patients with inhalation injury had a significantly higher ISS. Although we excluded all patients with thoracic

trauma and thoracic surgery, such injuries can also result in an increased incidence of ALI/ARDS. Furthermore, the mean time from burn injury to CT scan was approximately 2 days. Although the time to CT scan in our group comparisons did not differ significantly, this delay may impact on CT scan findings. In many cases, bronchoscopy preceded CT scans of the chest; therefore, findings on CT could not be accurately correlated with bronchoscopic findings, which may have been absent at the time of the CT. The optimal timing for CT scans should be elucidated in future prospective studies.

Another limitation of our study was the use of a composite endpoint. Here, we sought to combine clinically relevant endpoints (mortality, pneumonia, and ALI/ARDS). We used these because they are commonly accepted as direct sequelae of inhalation injury. We also retrospectively reviewed the medical records to ensure that the diagnosis of pneumonia and ALI/ARDS was accurate. The Murray Lung Injury score might have provided a useful endpoint as well, but we did not have the data on pulmonary compliance required to calculate this score.

The CT scans were assessed by an experienced radiologist who was blinded to the subject grouping, but we did not assess interrater reliability in this study. One of the objectives of our study was to determine whether CT findings were indeed quantifiable. As RADS is a novel method, we had to approach each CT scan systematically. As a result, calculating RADS was a labor-intensive retrospective process that will require refinement into a more clinically applicable tool. Also, the risks and benefits of CT scan in acutely injured patients should be carefully weighed.

In conclusion, admission CT may assist in predicting future lung dysfunction. Based on the findings of this study, a future prospective, randomized study is warranted to fully assess the utility of combined CT scan grading and bronchoscopy for assessment of pulmonary injury in burn patients.

ACKNOWLEDGMENTS

REFERENCES

1. Latenser BA, Miller SF, Bessey PQ, et al. National Burn Repository 2006: a ten-year review. J Burn Care Res 2007;28:635–58.
2. McGwin G Jr, George RL, Cross JM, Rue LW. Improving the ability to predict mortality among burn patients. Burns 2008;34:320–7.
3. Ryan CM, Schoenfeld DA, Thorpe WP, Sheridan RL, Cassem EH, Tompkins RG. Objective estimates of the probability of death from burn injuries. N Engl J Med 1998;338:362–6.
4. Mlcak RP, Suman OE, Herndon DN. Respiratory management of inhalation injury. Burns 2007;33:2–13.
5. Shirani KZ, Pruitt BA. The influence of inhalation injury and pneumonia on burn mortality. Ann Surg 1987;205:82–7.
6. Edelman DA, Khan N, Kempf K, White MT. Pneumonia after inhalation injury. J Burn Care Res 2007;28:241–6.
7. Darling GE, Keresteci MA, Ibañez D, Pugash RA, Peters WJ, Neligan PC. Pulmonary complications in inhalation injuries with associated cutaneous burn. J Trauma 1996;40:83–9.
8. Rabinowitz PM, Siegel MD. Acute inhalation injury. Clin Chest Med 2002;23:707–15.
9. Chung KK, Wolf S, Renz E, et al. High frequency percussive ventilation and low tidal volume ventilation in burns: a randomized controlled trial. Crit Care Med 2010;38:1970–7.
10. Chou SH, Lin SD, Chuang HY, Cheng YJ, Kao EL, Huang MF. Fiber-optic bronchoscopic classification of inhalation injury: prediction of acute lung injury. Surg Endosc 2004;18:1377–9.
11. Hunt JL, Agee RN, Pruitt B. Fiberoptic bronchoscopy in acute inhalation injury. J Trauma 1976;16:218–24.
12. Bingham HG, Gallagher TJ, Powell MD. Early bronchoscopy as a predictor of ventilatory support for burned patients. J Trauma 1987;27:1286–8.
13. Liffner G, Bak Z, Reske A, Sjöberg F. Inhalation injury assessed by score does not contribute to the development of acute respiratory distress syndrome in burn victims. Burns 2005;31:263–8.
14. Khoo AK, Lee ST, Poh WT. Tracheobronchial cytology in inhalation injury. J Trauma 1997;42:81–5.
15. Masanes MJ, Legendre C, Lioret N, Maillard D, Saizy R, Lebeau B. Fiberoptic bronchoscopy for the early diagnosis of subglottal inhalation injury: comparative value in the assessment of prognosis. J Trauma 1994;36:59–67.
16. Teixidor HS, Rubin E, Novick GS, Alonso DR. Smoke inhalation: radiologic manifestations. Radiology 1983;149:383–7.
17. Peitzman AB, Shires GT III, Teixidor HS, Curreri PW, Shires GT. Smoke inhalation injury: evaluation of radiographic manifestations and pulmonary dysfunction. J Trauma 1989;29:1232–8.
18. Agee RN, Long JM III, Hunt JL, et al. Use of 133xenon in early diagnosis of inhalation injury. J Trauma 1976;16:218–24.
19. Schall GL, McDonald HD, Carr LB, Capozzi A. Xenon ventilation-perfusion lung scans. The early diagnosis of inhalation injury. JAMA 1978;240:2441–5.
20. Petroff PA, Hander EW, Clayton WH, Pruitt BA. Pulmonary function studies after smoke inhalation. Am J Surg 1976;132:346–51.
21. Gattinoni L, Caironi P, Pelosi P, Goodman LR. What has computed tomography taught us about the acute respiratory distress syndrome? Am J Respir Crit Care Med 2001;164:1701–11.
22. Park MS, Cancio LC, Batchinsky AI, et al. Assessment of severity of ovine smoke inhalation injury by analysis of computed tomographic scans. J Trauma 2003;55:417-27; discussion 427–9.
23. Reske A, Bak Z, Samuelsson A, Morales O, Seiwerts M, Sjöberg F. Computed tomography—a possible aid in the diagnosis of smoke inhalation injury? Acta Anaesthesiol Scand 2005;49:257–60.
24. Koljonen V, Maisniemi K, Virtanen K, Koivikko M. Multidetector computed tomography demonstrates smoke inhalation injury at early stage. Emerg Radiol 2007;14:113–6.
25. American Thoracic Society and the Infectious Diseases Society of America. Guidelines for the management of adults with hospital-acquired, ventilator-associated, and healthcare-associated pneumonia. Am J Respir Crit Care Med 2005;171:388–416.

26. Bernard GR, Artigas A, Brigham KL, et al. Report of the American-European consensus conference on ARDS: definitions, mechanisms, relevant outcomes and clinical trial coordination. Intensive Care Med 1994;20:225–32.
27. Woodson LC. Diagnosis and grading of inhalation injury. J Burn Care Res 2009;30:143–5.
28. Ichikado K, Suga M, Muranaka H, et al. Prediction of prognosis for acute respiratory distress syndrome with thin-section CT scan: validation in 44 cases. Radiology 2006;238:321–9.
29. Nöbauer-Huhmann IM, Eibenberger K, Schaefer-Prokop C, et al. Changes in lung parenchyma after acute respiratory distress syndrome (ARDS): assessment with high-resolution computed tomography. Eur Radiol 2001;11:2436–43.
30. Owens CM, Evans TW, Keogh BF, Hansell DM. Computed tomography in established adult respiratory distress syndrome. Correlation with lung injury score. Chest 1994;106:1815–21.
31. Gattinoni L, Caironi P, Valenza F, Carlesso E. The role of CT-scan studies for the diagnosis and therapy of acute respiratory distress syndrome. Clin Chest Med 2006;27:559-70.
32. Palmieri Tina L. Inhalation injury: research progress and needs. J Burn Care Res 2007;28:549–53.
33. Endorf FW, Gamelli RL. Inhalation injury, pulmonary perturbations, and fluid resuscitation. J Burn Care Res 2007;28:80–3.
34. Cancio LE, Chavez S, Alvarado-Ortega M. Predicting increased fluid requirements during the resuscitation of thermally injured patients. J Trauma 2004;56:404–14.
35. Reper P, Wibaux O, Van Laeke P, Vandeenen D, Duinslaeger L, Vanderkelen A. High frequency percussive ventilation and conventional ventilation after smoke inhalation: a randomised study. Burns 2002;28:503–8.
36. Hall JJ, Hunt JL, Arnoldo BD, Purdue GF. Use of high-frequency percussive ventilation in inhalation injuries. J Burn Care Res 2007;28:396–400.